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ABSTRACT

An aim of many students of human development is to penetrate behavioral variability in such a way as to reveal stable phenomena. This broad aim is challenged on numerous fronts when researchers study infant behavior, for students of infants are everywhere confronted with variability. But, in the context of research, variability of subjects' performance is often viewed as undesirable. Major errors in science occur when researchers look for results in the wrong place or use inappropriate measures in search of lawful relationships. Such errors may be committed when ubiquitous phenomena are classified as "noise" which obscures the revelation of lawful events. It is the thesis of this paper that variability of behavior is one such phenomenon. Evidence presented in support of this thesis focuses on issues related to (1) the development of the Neonatal Behavioral Assessment Scale, (2) Linn's (1983) findings of behaviorally stable and behaviorally variable groups of infants, which lead researchers to take the fact of variability across test examinations as an informative indicator in and of itself, and (3) subsequent studies forcing investigators to seriously consider variability as a dimension of behavior which may facilitate development. It is pointed out that nearly 15 years had passed before researchers were able to see variability data as important information relevant to processes terminate adequacy of the development of normal and at-risk infants. (RH)

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Variability as a Dimension of Infant Behavior

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In the developmental sciences, particularly as they pertain to human behavioral development, we can probably identify several kinds of scientific emphases. One is phenomena oriented focus with perhaps a developmental orientation. This point of view reflects interest in specific kinds of behaviors as phenomena - when they occur, under what conditions they occur, how they change, what meaning they have in the larger scheme of behavioral development. You can think of many examples of these kinds of phenomena and this meeting is filled with reports of them. The concurrent symposia at this hour are exemplars: mother-infant separation; stress; attention to auditory and visual stimuli.

PS 016 163

Another emphasis relates to individual differences - how they can be described, how stable they are over time, when they first appear reliably, what meaning they have for later developmental status. There are fewer examples of these reflected in the program for this meeting but there are some: A symposium on individual differences in facial expression; a poster session on

individual differences and prediction; a poster session on antecedents, correlates and consequences of individual differences in infant attention.

Interestingly, behavioral variability is an anathema to both kinds of efforts. Those concerned with specific phenomena are interested in the detection of behavior and understanding how it functions. Research on these topics often uses the traditional methodology of group design. Typically, in the evaluation of results the statistical analysis provides for determining whether the variance of the measures that can be attributed to the specified variables in the study is sufficiently of greater magnitude than the variance that can be attributed to everything else. If it is, then one can conclude that the results are a function of those designated variables. Variability is seen as a "noise" factor and the question of the analysis is whether the signal to noise ratio is of such a degree as to conclude that one is observing more than noise. Because this strategy involves an aggregation over subjects to "wash" the variability associated with subject and other differences, the results could be an artifact of averaging and actually not represent the behavior or characteristics of any individual subject.

A reaction to the aggregated approach is found in the operant strategy which eschews the group design in favor of single subject design. In this strategy the effort is to study one subject, get an effect that appears to be the result of an experimental

manipulation, replicate on another subject and another and another. If the pattern of results is found across subjects a conclusion is drawn attributing the result to the manipulated variables. It is assumed that there will be variability between subjects but one is looking for a stable pattern to emerge across subjects. Variability is seen as noise and the question is whether the signal (the pattern) to noise ratio is, by eyeball inspection, sufficiently strong to conclude that the variables of interest are responsible for the effects revealed in the pattern. The pattern is not an aggregrate. It is typical of individuals; hence, the inference to individual behavior is seen as stronger than in the group design strategy.

In both of these approaches, then, variability is thought of as a nuisance element. Investigators are trained to minimize the influence of those variables of no interest that might contribute to variability.

In the traditional group design approach, because we cannot totally eliminate the supposedly extraneous sources of variability, we find ways to estimate the value of the signal to noise ratio. We have an extensive array of statistical techniques to help us make that evaluation and justify inferences to effects beyond the operation of chance. Thus, variability and chance become linked partners in how we think about the phenomena we study. The underlying theoretical basis for almost all statistical techniques involves assumptions about variability in

the universe and variability in the sample. The mind-set is to get beyond variability, to penetrate variability in such a way as to reveal real, stable phenomena and patterns . . . i.e., the reliable laws of behavior.

The individual difference focus is similarly afflicted. Studies aimed at understanding individual differences focus upon characteristics associated with individuals and look at those characteristics relatively from individual to individual. The concomitant psychometric approach for determining whether or not there are reliable individual differences on a particular measure or in a particular situation relies upon comparing the relative ranking of individuals over more than one occasion. Stability of performance over repeated assessments is one of the hallmarks of an acceptable individual difference measure. An estimate of that stability is to be found in every manual for every psychological test.

Variability in performance over repeated examinations is viewed as undesirable. It is recognized that it is unlikely that we will find identical performance from occasion to occasion so the question is whether the degree of variability over testing times is sufficiently low as to make the test acceptable. We have a whole cadre of conventions for evaluating this and for determining what are tolerable levels of variability. The resulting mind-set is to look for stability and to use measures which can be demonstrated to yield stable performance over time.

This mind-set is challenged on numerous fronts when doing infant research. Infant researchers are, everywhere, confronted with instabilities, with variability, with seemingly constantly changing performance. This is over and above the well-known phenomenon of a rapidly developing behavioral repertoire wherein new behaviors come in to the repertoire and already acquired behaviors undergo major changes in topography. When some standard infant tasks are investigated for test-retest reliability the results can be surprising though this has not been a focus of many investigators. It has been a focus at Kansas. John Colombo, Marion O'Brien and Wayne Mitchell have been conducting an extensive program of research on the short- and long-term stability of infant habituation behavior. They have noted that, with the exception of the duration of peak fixation, and some non-peak duration measures many of the parameters related to the habituation-dishabituation task show little or no short- or long-term stability (Colombo, Mitchell, O'Brien and Horowitz, 1986).

Indeed, these kinds of findings along with the failure to demonstrate long-term prediction from measures of infant behavior to later developmental status, have led a number of developmentalists to declare that there is no continuity between infancy and later development (Kagan, Kearsley, and Zelazo, 1978; Scarr-Salapatek, 1976).

Such declarations are likely premature. Recent reconceptualizations of the nature of intelligence (Sternberg,

1985) and of the importance of the response to novelty as a key component in intelligence (Berg and Sternberg, 1985) ought to encourage caution in resting the case in favor of discontinuity. Scientific advancement is, in part, determined by scientists finding the right measures for revealing lawful phenomena. A source of major error in science is to look in the wrong place or to use the wrong measures in search of lawful relationships.

Sometimes such errors are committed by overlooking ubiquitous phenomena, phenomena that have been classified as nuisance phenomena, as the noise obscuring the revelation of lawful events. It is the thesis of this paper that variability of behavior is one such phenomenon. I shall present today evidence from a number of studies that can be used to support this thesis.

Interest in this matter was first stimulated when I became involved with Berry Brazelton in the development of the Neonatal Behavioral Assessment Scale (Brazelton, 1973). Because of the nature of the newborn infant's behavioral repertoire, it became immediately obvious that many of the standard psychometric conventions were not appropriate for this kind of assessment. For instance, there could not be a fixed order for presentation of scale items because the given items required the presence of given states and these were not always available on examiner demand. Another example - because the strategy of the examination required

the examiner to elicit the infant's best behavior, the notion of fixed number of presentations of stimulus items or behavioral probes was not justified.

Nevertheless, consumers of the NBAS still approached the examination as a standard test tool and looked for the traditional indices of merit of a psychometric evaluation. First, of course, was reliability of scoring of items. This is an undisputed requirement for any kind of objective measure. The reliability of NBAS item scoring was demonstrated at acceptable levels. Second, there was the question of test-retest reliability. The standard Pearson r analyses of performance on items over two examinations have typically revealed low to moderate correlations (Sameroff, 1978). Yet, in the initial publication of the manual for the NBAS, a different estimate of reliability was used. Or, rather stability of performance. The traditional Pearson r evaluates the performance of an individual relative to the performance of other individuals and gives you an estimate of the stability of that relative ranking. What was first reported for the NBAS with regard to stability was not the Pearson r, but a measure of agreement of individual scale item scores over repeated examination for each subject. The measure compared performance on scale items at one time with the same individuals' performance on scale items at another time. Self (1971) found that the mean

stability for 30 male infants was .59 for exams given at three days of age and at four weeks of age and .65 for 30 female infants.

Further, the range of stabilities over this four week period was large. One male infant had a test-retest stability as low as .24; the lowest test-retest stability among female infants was .42. The highest test-retest stabilities over four weeks for males and females, respectively was .78 and .85. The significance of this range was not remarked upon in the first NBAS manual (Horowitz and Brazelton, 1973). But the traditional notion of reliability was asserted, and variability down played. "At one month of age considerable changes have occurred in the baby and it is to be expected that scores on the battery will be different. Despite this, however, a strong suggestion of the relationship between the early and later assessment is apparent from the data reported here." (p. 50).

Five years later, in 1978 Horowitz, Sullivan and Linn were questioning the desirability of stability of neonatal performance over the first month of life in the context of a theoretical analysis. Here it was proposed that the reason for moderate levels of stability over the first month was due not only to the changing nature of the behavioral repertoire/profile of the infant from a developmental point of view, but also from the intrusion of differential environmental experiences during this period. Again,

the sine-qua-non was stability; the explanation for low stability was being sought; the presence of variability was to be explained away.

In 1980 Lancioni, Horowitz, and Sullivan reported on stabilities of items of the NBAS with Kansas supplements and noted the percentages of subjects receiving the same score $\pm$ 1 on each of the items with exams given repeatedly on days 1, 2, 3, at two weeks and at one month of age. The mind-set for reliability was again evident when we concluded that if one were interested in which evaluation gave you the most reliable estimate of the infant's behavior it was best to do the assessment at two weeks of age.

It was not until Linn's dissertation, carried out in 1979 and published in 1983, that we began to take seriously the fact of variability over test examinations as an informative indicator in and of itself. Linn's sample consisted of 27 infants born to low SES mothers who were tested on two consecutive days in the hospital (Days 2 and 3). She found, as we had found already in 1971, that some infants showed relatively similar performance over two examinations; others quite a bit less. The range in her sample was from a low of .18 to a high of .73. The sample divided out about evenly with respect to infants who showed .50 or higher stability on the two exams and those who showed .49 or lower stability. The latter group we called variable, the former stable.

We began to use this information as an individual difference characteristic. When we compared the results of an independent observation of mother-infant interaction in the hospital for the variable and stable infants we found that, contrary to our intuitive hypothesis, the variable infants were more likely to be involved in an interaction with a mother who was classified as generally responsive; the stable infants were more likely to be involved in an interaction with a mother who was classified as generally unresponsive.

Insert Table 1 about here

Buddin, using some of Linn's subjects and adding others, replicated this finding by comparing performance on the NBAS-K at two and four weeks of age, classifying the infants as variable or as stable and looking at the relationship of this to interaction with the mother at four weeks of age. As seen in Table 2 the variable infants were more likely to be involved in interaction with mothers judged as responsive, the stable infants more likely to be involved in interactions with mothers judged as unresponsive (Horowitz, Linn, and Buddin, 1983). Woroby (1986) has just published a partial relication of this finding.

Insert Table 2 about here

A hint of the possible long term significance of these results was reported by Horowitz, Linn, Smith, and Buddin (1981) when they followed up and found six of Buddin's 20 subjects when they were a year old. The Bayley Mental Scores on these infants ranged from 86 to 115. At one year of age there was an almost perfect correlation between level of maternal responsivity and infant responsivity at four weeks of age and Bayley Mental Score such that the most highly responsive mothers and infants at four weeks of age predicted the higher Bayley scores at one year while the less responsive mothers and infants at four weeks had the lower Bayley scores.

The consistency of these kinds of relationships has finally forced us to take variability seriously as a dimension of behavior which may have facilitative import as far as development goes. When we first noted the relationship between variability and maternal responsivity Bob Emde (1978) commented that variability may have an evolutionary advantage in relation to a greater flexibility of the behavioral repertoire and, we might add, in relation to eliciting greater maternal responsivity. These kinds of relationships may be facilitative of normal development. Given the greater likelihood of normal development in normal term babies compared to preterm, higher risk infants, we would predict differential patterns of variability and stability of repeated neonatal assessments in these two populations. We were able to test this hypothesis by comparing a group of preterm infants being

studied by Susan Schwartz in our lab group with a group of normal infants who had been repeatedly tested by Lancioni. We had a sample of 44 preterm infants for whom we had a minimum of four neonatal assessments using the NBAS-K with some preterm qualifier scales (Schwartz, Horowitz, and Mitchell, 1985).

The preterm infants were assessed twice in the hospital, after the infant weighed at least 2,000 grams, had been transferred out of the isolette for at least 12 hours to an open crib and was free of medical complications. These assessments took place approximately 2-3 days before discharge. A third and a fourth evaluation was done at two and four week post-discharge.

In developing and testing the NBAS-K, Lancioni (Lancioni, Horowitz, and Sullivan, 1983) tested 107 normal, term babies on five occasions: at one, two and three days of age, at two weeks of age and at four weeks of age.

For each infant in each sample we made some simple calculations. We took each examination and made a comparison to every other examination with respect to the number of items on which the score was the same ("same" is defined as the exact score or a score disagreed by one scale score point). This serves as the basic measure of stability of performance. We would predict that preterm infants would, on the whole, have higher levels of stability than normal infants. Or, conversely, that we would see greater variability on test-retest comparisons for normal infants.

We looked at the data for these two samples in two ways. First, we took a mean stability for each infant across all the test comparisons. A display of the distribution of those means is shown in Table 3. As can be seen, almost 60% of the normal infants have stability scores below .60 while the comparable figure for the preterm infants is 43%.

Insert Table 3 about here

Eighteen percent of the preterm sample had a mean stability score above .70 while less than one percent of the normal infants had stability scores that high.

If one looks not at the mean across all exams but at the distribution of the percentages for all the exam comparisons a similar picture emerges. For the preterm sample, we have a total of 264 exam comparisons: four exams for 44 infants, yielding six comparisons for each infant. For the normal sample of 107 infants we have a total of 1070 comparisons. Table 4 displays

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Insert Table 4 about here

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the distributions of percentages of stability levels for each sample. In the preterm sample over 82% of the sample has stability levels at 50% or above. In the normal term sample the comparable figure is a little less than 73%. The most dramatic

differences are at the high end of the distribution. More than 10% of the preterm sample is showing stabilities at .80 or above while this figure is a little over 4% for the term sample. Almost 9.5% of the term sample is showing stabilities at .30 or less while only a little less than 5% of the preterm sample is showing stabilities at this level.

Based upon the data reported here the preterm babies with higher levels of stability and the term babies with higher levels of stability would be expected to more likely to be involved in interactions where mothers demonstrate less responsivity. Since a greater percentage of preterm babies show the higher levels of stability we would expect less instances of maternal responsivity in mother-infant interaction episodes in the preterm group. This may provide a clue to the kinds of infant individual differences that contribute to poorer subsequent developmental outcome in preterm infants.

The title of this paper is: "Variability as a Dimension of Infant Behavior." It could carry the subtitle of: "A Story of Delayed Recognition." We have known for more than fifteen years that some infants show high levels of stability from test to retest, others quite low levels. But it has taken much of this time to turn the mind-set from seeing these data as disquieting indicators of an unacceptable psychometric to a piece of important

information that we should be using to put together the puzzle that will tell us about the variables that enter into the processes that determine the adequacy of the developmental course of normal and at-risk infants.

One must be cautious, though. Variability is a dimension of infant behavior, not the dimension. It is possible that in some behavioral domains or areas that stability is a more facilitative characteristic than variability. Tynan (1986) has reported that stable state patterns are predictive of developmental outcome in a sample of infants cared for in a neonatal intensive care unit. In this case the higher the stability index, the better the developmental outcome. State is an important component in the Neonatal Behavioral Assessment Scale and it would be interesting to determine the sources of stability and variability on NBAS exams as a function of state requirements. Colombo (1986) has speculated that state variables may provide a better picture of the young infant than stimulus information processing variables for purposes of prediction.

In our laboratory Moss (1985) has shown that the Range of State Lester Cluster score for normal newborns on the NBAS-K predicts recovery of attention at three months of age in an habituation/dishabituation paradigm in the laboratory. Thus, infants who had a more optimal range of state were significantly more likely to dishabituate to a new stimulus than infants who had a less optimal range of state.

Taking the issues of state consistency, NBAS scale score variability and optimal range of state, it is possible that consistency in state variability and high levels of variability on NBAS scale items are jointly predictive of better subsequent behavioral functioning. It is unlikely that any single variable or any single measure will be the key to understanding developmental outcome.

We must try to understand the processes by which developmental outcome is determined. The impressive data reported by Siegel and her colleagues. (Siegel, 1982 a; b; 1985; Siegel et al., 1982) using gross demographic, perinatal and reproductive variables to predict the developmentally at-risk children in preterm and normal samples supports the notion of [redacted] using multiple variables. But, these kinds of variables do not, themselves, illuminate the processes which determine developmental outcome. For this we need measures and dimensions of behaviors where we can track how these measures and dimensions operate in the processes. Variability, and ranges of stability of state may provide useful parts of the picture of the processes involved.

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Footnotes

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Table 1

General Responsivity

NBAS-K	Responsive	Unresponsive
Stable	5	10
Variable	8	4

Kendall's Tan B = -.33
($p < .05$)

From Linn and Horowitz, 1983.

Table 2

Maternal Responsivity in Mother-Infant Interaction at 1-month and Infant NBAS-K Stability (2-wks & 1-mo.)

Mother-General Responsivity

Infant NBAS-K	Responsive	Unresponsive
Stable	1	9
Variable	5	5

Kendall's Tau signif < .05

Mother-Talking Responsivity

Infant NBAS-K	Responsive	Unresponsive
Stable	1	9
Variable	8	2

Kendall's Tau signif < .001

Mother-Cuddling Responsivity

Infant NBAS-K	Responsive	Unresponsive
Stable	3	7
Variable	7	3

Kendall's Tau signif < .05

From Horowitz, Linn and Buddin, 1983

Table 3

Distribution of Mean Levels of Stability Across Repeated[1] NBAS Examination Comparisons for Term and Preterm Infants

Mean Stability Level	Term Infants N = 107		Preterm Infants N = 44	
	n	%	n	%
0 - 10	0	0	0	0
10 - 19	0	0	0	0
20 - 29	0	0	0	0
30 - 39	0	0	0	0
40 - 49	14	13.03	3	6.82
50 - 59	49	45.79	16	36.36
60 - 69	42	39.25	17	38.64
70 - 79	2	2.00	8	18.18
80 - 89	0	0	0	0
90 - 100	0	0	0	0

[1]Term infants tested at 1, 2, 3, days at 2 weeks and at 4 weeks, Preterm infants tested twice in hospital just prior to discharge, two and four weeks post discharge.

Table 4

Distribution of Stability Levels for Term and Preterm Infants on the NBAS-K Over Repeated Examinations

	Term Infants N = 107		Preterm Infants N = 44	
Stability Level	n	% of Comparisons	n	% of Comparisons
0 - 10%	0	0	0	0
10 - 19%	0	0	0	0
20 - 29%	21	1.96	4	1.52
30 - 39%	80	7.49	9	3.41
40 - 49%	191	17.85	34	12.88
50 - 59%	298	27.85	66	25.00
60 - 69%	294	27.48	76	28.79
70 - 79%	143	13.36	47	17.80
80 - 89%	35	3.27	25	9.47
90 - 100%	8	.75	3	1.14

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